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DEPARTMENT OF NATURAL RESOURCES AND ENERGY
MINERALS AND ENERGY DIVISION

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PROCESSING OF SELECTED NEW BRUNSWICK GOLD RESOURCES

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FREDERICTON, N.B.

by

R.D. Harris, P.Eng.

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PROCESSING OF SELECTED NEW BRUNSWICK GOLD RESOURCES

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Copies available by contacting:

Minerals and Energy Division
Department of Natural Resources and Energy
P.O. Box 6000, Fredericton
New Brunswick E3B 5H1

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Abstract

Gold mineralization has been found in several areas of New Brunswick. This study assessed the processability of three of these areas: the Alcida deposit (held by Corona Corporation), the Cape Spencer deposits and the Lake George gold occurrence (Durham Resources Inc.). These areas were selected on the basis of their accessibility as well as their potential as gold ore types.

Leaching experiments for gold extraction using sodium cyanide indicated that the Cape Spencer gold is non-refractory and therefore susceptible to leaching action, whereas the other two locations were found to be highly refractory and not amenable to direct cyanidation. The study included gravity and flotation tests as well as brominated hydantoin (Bio-d) leaching of the Cape Spencer deposits. Both Lake George and Alcida require extensive oxidation treatment (i.e., exposing the gold to render it recoverable by the cyanidation leaching process).

Résumé

Des dépôts aurifères ont été découverts dans plusieurs régions du Nouveau-Brunswick. Une étude a permis de confirmer que trois de ces sites étaient exploitables: le gisement Alcida (détenu par Corona Corporation), les gisements de Cape Spencer ainsi que le gisement du Lac George (Durham Resources Inc.) Ces trois sites ont été sélectionnés en raison de leur accessibilité et des types de minerais d'or qu'on risque d'y retrouver.

Les tests d'extraction du minerai à l'aide du procédé de lessivage au cyanure de sodium ont indiqué que l'or du gisement de Cape Spencer est non réfractaire et qu'il est donc très sensible au procédé de lessivage, tandis que les deux autres gisements sont hautement réfractaires it ne sont donc pas sensibles au processus de cyanuration directe. L'étude prévoyait également des tests de pesanteur et de flottation ainsi que le lessivage à l'acide hydantoique brominé (Bio-d) pour le gisement de Cape Spencer. Les gisements du Lac George et d'Alcida requièreront tous deux d'importants traitements d'oxydation (exposition de l' or afin de le rendre récupérable à l'aide du prodécé de cyanuration).

1.0 INTRODUCTION

1.1 Objective

The primary objective of this project is to generate base-line processing data on several potential gold ores within the Province of New Brunswick and to determine their refractoriness with respect to conventional recovery (leaching) processes.

1.2 Scope

The work focused on gold samples from three in-province locations: 1) the Alcida deposit of the Bathurst area, 2) the Lake George antimony mine of Durham Resources Inc., and 3) the Cape Spencer deposits (Gordex Minerals Limited and Mispec Resources Inc.) in the southern part of the Province. Leaching test work was conducted on the samples using sodium cyanide as the main leachant and brominated hydantoin (Bio-d) for specific samples; both rolls and column leaching techniques were used. Basic optical mineralogy and a suite of cursory gravity concentration tests were also completed for all samples from the three locations.

1.3 Project Background

The work described herein has focused on test samples taken from three in-province locations having known gold mineralization[1]. These locations have included the Alcida gold deposit of northern New Brunswick held by Corona Corp., the Cape Spencer deposits of southern New Brunswick held by Mispec Resources Inc. and Gordex Minerals Ltd., and the gold occurrence at the Lake George antimony mine held by Durham Resources Inc. These areas were selected on the basis of sample availability and ore potential.

The processability of these potential ores will vary as a function of their mineralogical makeup and their gold-to-matrix association. It has been shown in many instances that gold occurs in asssociation with different matrix types, ranging from sulphide to quartz. Mineralogical factors determine how particular gold ores respond to different processing methods.

Refractoriness is a primary consideration in the processing of any gold-containing ore matrix. This characteristic reflects largely the extent of processing one could expect in order to achieve acceptable (economical) recoveries. The term refractory, in this context, refers to an association (of gold) that is not typically amenable to processing or recovery by direct leaching using a leachant such as sodium cyanide. The distinction between a refractory and a non-refractory ore, in terms of recovery by direct leaching has not been well defined in quantitative terms. However, as a very general rule, an ore of refractory nature would yield less than 80% of the gold upon direct cyanidation at fairly coarse feed sizes (greater than 6.4 mm)[2,3].

With sharp improvements in the price of gold realized at the beginning of the decade, exploration and development of gold properties throughout North America and elsewhere have been increasing at a heated pace. This has been the case for New Brunswick.

In similar fashion, the technology relating to the extraction and recovery of gold from its ores has undergone marked improvements over the last twenty years or so. These improvements have contributed to the current healthy position of the gold industry or, for that matter, the precious metals industry in general. Many low-grade deposits considered to be uneconomic years ago are now becoming sources of opportunity because of the synergism afforded by these technological and economic factors.

The gold sector of the New Brunswick mineral industry has shown good development over the last ten years, as many good prospects and deposits have been identified (e.g., Cape Spencer and the Murray Brook deposits in the northern region). These resources will require further work and definition before their true economic value, if any, is realized.

Within this sector, the Province through funding provided under the current Mineral Development Agreement (MDA) commissioned this study as a way of generating base-line information on these developing resources. The hope is that this information will furnish in-province developers with some understanding of the processing difficulties associated with certain "ores". This should lay the groundwork for further process development by industry as a complement to their progressive resource development efforts.

2.0 TESTING AND METHODOLOGY

2.1 Rolls and Column Leaching Techniques

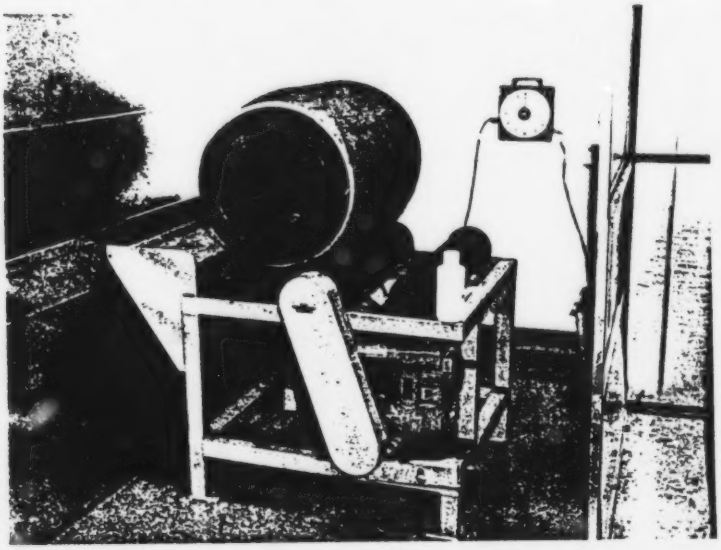
The laboratory assessment of the leachability of gold-containing rock samples usually encompasses bottle rolls and column simulations of the leaching process[3]. Rolls testing is the more basic of the two, and it is used to give some indication of the susceptibility of a given sample to leaching under agitated (ideal) conditions. The results of such testing provide some definition of the relationship between the consumption, concentration and type of leachant used and the resulting recoveries of gold. If promising, these results may then be used to provide the basis for column test work under static ore conditions. The column studies give data that is more representative of the effectiveness of the heap leaching extraction process.

The rolls technique is a rather simple test to perform. Firstly, the sample in our case is ground to -200 mesh in a laboratory ball mill, where it is then split, weighed and placed into several plastic containers (measuring approximately 13.3 cm in. in length and 6.3 cm in diameter). Each container is loaded with approximately 100-150 g of prepared ore sample. The leachant, being either sodium cyanide or Bio-d, is then charged to each container in varying concentrations; the number of containers used for each test is dependant on the range and increments of the parameters (e.g., leachant concentrations, pH, etc.) to be tested. For sodium cyanide, the pH of the solution was adjusted to at least nine before addition of this leachant so as to prevent the formation of cyanide gas within the process solution. (At around pH 8.5 and below, gaseous hydrogen cyanide is formed and driven off from the process solution.)

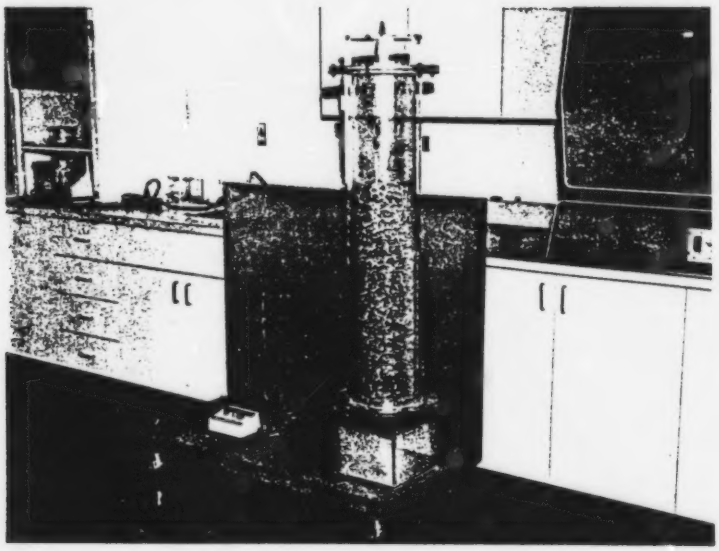
After charging the containers appropriately, they are placed collectively in a sealed plastic drum that is then laid on its side on an adjustable-speed drive roller for agitation purposes (shown in Figure 1(a)). The agitation or mixing action of the test samples is brought about by the revolution or rolling of the drum on this powered roller mechanism (hence "rolls test"). The samples are agitated continuously for about 48 hours, which is usually sufficient time for the leaching reactions to reach virtual equilibrium conditions.

The final leached products are then filtered and assayed to determine the gold content of both the liquid and solid phases. The assay data are then used to calculate the appropriate mass balances for determining gold recovery under the various leachant concentrations tested. Gold extraction versus cyanide consumption relationships are then generated for assessment purposes (Section 3.0).

The column simulation technique is fairly straightforward but more involved than the rolls technique. Column simulation is more representative of the commercial



a) Rolls Test Apparatus



b) Column Leaching Apparatus

FIGURE 1. LEACHING TECHNIQUES AND EQUIPMENT

heap-leach process since it is conducted under static conditions and gives a better understanding of the recoveries one could expect from such a process. The rolls test is usually a prerequiste to the column work since the preliminary data generated by the former would determine whether column leaching is warranted. The leachant used throughout this column work was sodium cyanide.

The column used in this study (Figure 1b) is constructed of plastic pipe measuring 20.3 cm in diameter and 1.21 m in height. It has the capacity to hold approximately 50 kg of crushed ore. The diameter of the column was designed to be at least 6 times that of the largest ore particles in order to minimize the effects of solution channelling down the column. The complete circuit is based on the closed-loop principle so as to maintain careful inventory control for mass balance determinations.

Having charged the column with a known mass of ore sample, a controlled volume of caustic (sodium hydroxide) solution at a pH of around 11 is then introduced to the system via a peristaltic pump. This solution (about 30 L) is recirculated through the system over an average period of 24 hours to ensure pH stability before introducing the sodium cyanide leachant.

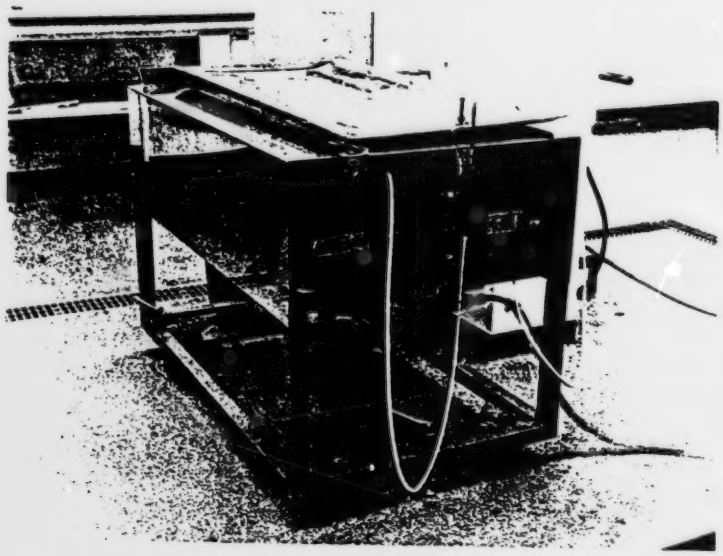
The leach solution is pumped to the top of the column where it is allowed to trickle onto the ore at a rate of approximately 8 cm^3/min. An absorbing cloth placed over the top of the static ore heap allows for even distribution and contact of the trickled leach solution over the cross-sectional area. The solution percolates down the column, is collected in a reservoir that forms the base of the column unit, and is pumped to the top of the column. Before reaching the top, the pregnant leach solution passes through three activated carbon columns that adsorb and recover the gold (gold cyanide complex). A typical leaching test lasts about 35 to 60 days and requires continuous recirculation of the leach solution during this time.

Each of the three carbon columns has the capacity to hold between three and four grams of activated carbon. The amounts actually used are accurately determined before application. After seven days of continuous operation, the columns are replenished with fresh carbon. The spent or loaded carbon is removed for gold assaying. Makeup of the sodium cyanide leachant after gold recovery was not done in this test work because real time analytical support was not available; however, the losses were typically minimal on a stoichiometric basis. As well, the leach or process solutions are assayed periodically to monitor gold and other metal ions (e.g., Cu, Mg) in solution over the course of the test.

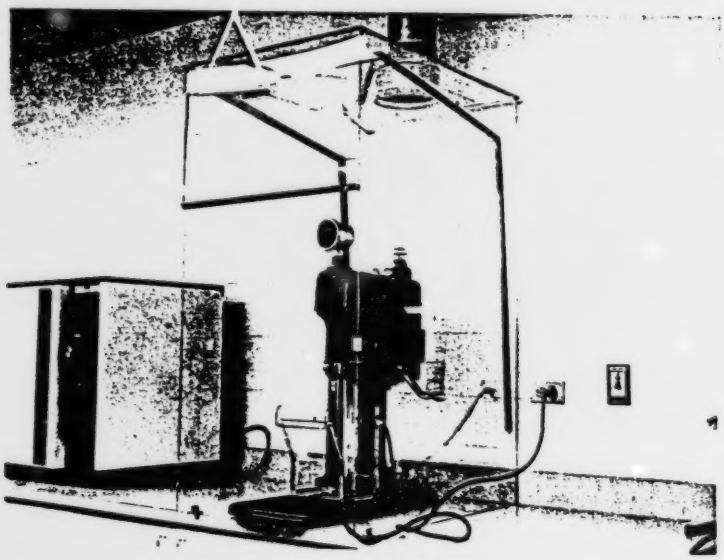
The important parameters to consider with respect to column leach test work are the dependency of leachant concentrations, percolation rate, crush size, and temperature on gold recovery and recovery rate. As mentioned earlier, the rolls tests provide some input on the appropriate range of leachant solution strengths and consumption as a basis for the column test work.

2.2 Mineral Beneficiation Techniques

For the mineral beneficiation work, a Mozley mineral separator and a laboratory flotation machine were used. The Mozley separator, based on a gravity principle, consists of a batch table configuration (Figure 2(a)). The flotation machine, a Denver model D-12, is used and well accepted by industry for laboratory flotation investigations (Figure 2(b)). With either technique, grade and recovery relationships will determine their applicability to or effectiveness on particular ore types.



a) Mozley Mineral Separator



b) Denver Flotation Machine

FIGURE 2. MINERAL BENEFICIATION TECHNIQUES

3.0 RESULTS AND DISCUSSION

3.1 Cape Spencer

Extraction tests performed on samples taken from the Cape Spencer area consisted mostly of rolls and column leaching experiments. To date, two major zones (deposits) have been identified in the area: the "Road Zone" on property held by Mispec Resources Inc. and the zone adjacent to the Gordex heap leach operation.

In both zones, the gold mineralization extends from the surface to depths of a hundred metres or more [6], which has given rise to some differences in gold association with depth. An important consideration is the degree of oxidation of the mineral matrix; mineralization at or near the surface tends to be considerably more oxidized than that occurring at depth. These differences in oxidation have some bearing on the processing method.

Rolls and column leaching were carried out under a range of conditions on both surface and core samples. Rolls tests were conducted on both Mispec and Gordex samples using two leachants: sodium cyanide and Bio-d.

The column simulation test work was carried out on core samples from the Mispec Property. No column work was done on the Gordex ore because of problems in getting sufficient sample.

The remaining test work was designed to determine the amenability of the Mispec surface ore to gravity concentration using the Mozley separator. It was felt that gravity may have some merit for this application since the surface

material is highly oxidized and consequently contains significant amounts of native (free) gold.

As well, an optical mineralogical investigation was done on both Mispec and Gordex samples to determine the associations of gold with other contained minerals. This investigation was completed under contract by Wittech Development Inc. of Ontario[7].

Mineralogy

Three samples from the Cape Spencer area were assessed individually for their mineralogical makeup and gold association. One sample consisted of core material whereas the other two were surface gold samples.

The gold in the core sample was predominantly associated with pyrite and, to a lesser extent, with Fe-Ti oxides. Although some native gold was observed, the main occurrence of gold was determined to be along microfractures in pyrite. Minimal oxidation of the pyrite was observed.

Both surface samples were highly oxidized, but to varying degrees. The primary minerals associated with the gold were pyrite, hematite and iron oxyhydroxides. The latter mineral species are, presumably, oxidation products of pyrite. Native gold was pervasive in both samples and was spatially associated with pyrite and its secondary oxidation products.

Sodium Cyanide Leaching

Preliminary rolls testing using sodium cyanide leachant was performed on Gordex surface and Mispec core samples. Head grades were 1.68 g/t Au and 0.37 g/t Au, respectively. These ores were tested separately for gold extractability under

various reagent (leachant) concentrations and solution strengths (Table 1).

In each test, the sample sieve size was -200 mesh (75 micrometres) and the test period was 48 hours. This mesh size was used in order to determine "maximum" reagent consumptions and gold recoveries, which form the basis for the column leaching experiments. The recoveries demonstrated by these tests are not indicative of recoveries achievable with column or commercial leaching processes because of the increased liberation afforded by the fine ore sizes and of the agitated reaction conditions.

The leachant solution strength was tested over the range of 0.45 to 3.57 g/L, with the respective leachant concentration (kg NaCN/t of ore sample) ranging from 0.699 to 5.352 kg/t. These ranges are considered to be typical of and consistent with current commercial leaching processes and practices[8].

TABLE 1

Results of Preliminary Rolls Testing of
Cape Spencer Gold Ore Samples

NaCN Soln. Strength (g/L)	NaCN Concentration (kg NaCN/t Ore)			
	0.699	1.338	2.676	5.352
	% Gold Recovery			
0.45	93.59	92.38	93.40	97.57
1.78	34.03	91.61	91.29	93.68
3.57	---	53.80	91.48	93.01

A) Results of Rolls Test of Gordex Surface Sample
Head Assay: 1.68 g/t Au Temperature: 22°C
Test Period: 48 hrs Sample Sieve Size: -200 Tyler Mesh
(75 micrometres)

NaCN Soln. Strength (g/L)	NaCN Concentration (kg NaCN/t Ore)			
	0.699	1.338	2.676	5.352
	% Gold Recovery			
0.45	47.93	75.17	85.63	81.12
1.78	---	66.90	91.55	78.65
3.57	52.40	---	88.24	86.88

B) Results of Rolls Test of Mispec Core Sample
Head Assay: 0.37 g/t Au Temperature: 22°C
Test Period: 48 hrs Sample Sieve Size: -200 Tyler Mesh (75 micrometres)

With few exceptions, the gold recoveries obtained from surface ore were consistently higher than those from core samples using similar reagent dosages. The differences in gold recovery are modest in most instances and may be due to the degree of sample oxidation. Oxidation is believed to be responsible for the increased liberation of gold during the leaching process.

Another factor, and perhaps the most significant, is the wide variation in head grades between the two samples. The ratio of gold content of the surface and core samples is approximately four to one, respectively. Such a ratio may give rise to disproportionate fractions of contained gold that are available for dissolution by the leachant.

There are a couple of other features that are important to recognize from these results. First, the difference in recovery between the maximum and minimum limits of the leachant dosages was insignificant or showed little dependency for the surface sample, whereas the difference for the core sample was nearly 40%.

However, recoveries for both samples showed modest improvements as both the NaCN solution strength and concentration are increased over the tested range.

Another rolls test was conducted on a Mispec core sample, having an average head assay of 2.20 g/t Au. This grade was considered to be more typical or representative of the Cape Spencer deposits[6]. This test was designed to determine gold recoveries over a narrower range of leachant conditions relative to the previous test work.

Table 2 presents the results of the leaching experiments conducted on the higher grade (Mispec) core material. For repeatability purposes, the experiments were carried out in duplicate using two separate sub-samples of the same bulk core sample. Both of these runs (Tests A and B) are shown in the table for comparison.

TABLE 2
Results of Rolls Testing of Mispec Core Material

NaCN Soln. Strength (g/L)	NaCN Concentration (kg/NaCN/t Ore)			
	0.50	1.00	1.75	3.00
	% Gold Recovery			
Test A				
1.00	5.49	98.59	--	--
2.00	--	--	92.23	98.53
Test B				
1.00	25.18	98.62	--	--
2.00	--	--	92.23	98.74

Head Assay: 2.20 g/t Au
Temperature: 22°C
Test Period: 48 hours
Sample Sieve Size: -200 Tyler mesh (75 micrometres)

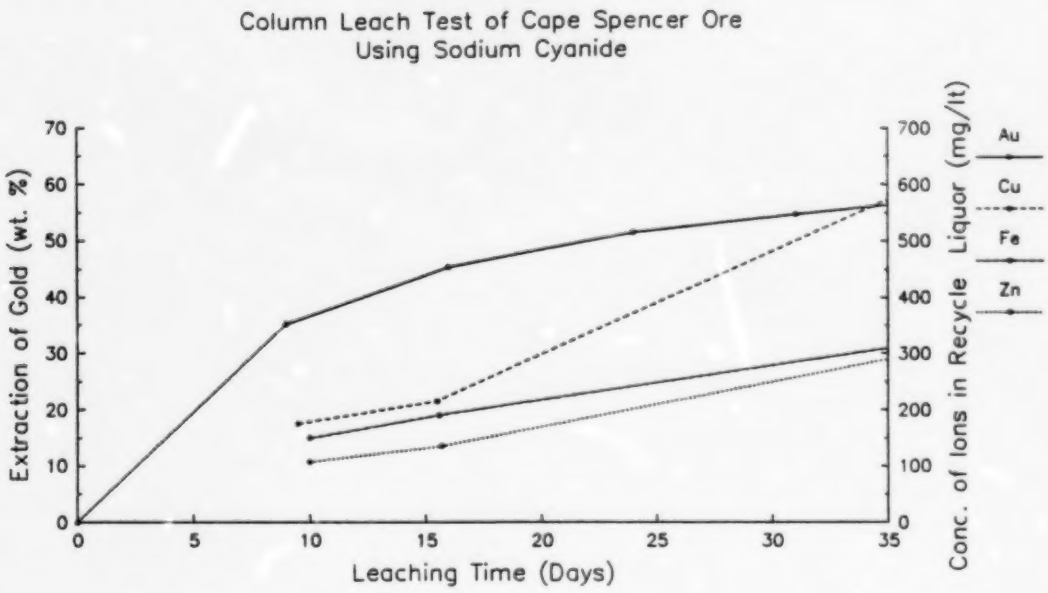
Apart from one obvious exception, the data showed good precision. The results or recoveries obtained indicate a general improvement over those of the earlier tests (Table 1(b)) using core material, despite modest differences in the actual leachant conditions. Such improvements may be the consequence of the sample head grades, which varied considerably between this and the previous test work.

For the initial column leaching experiments, it was decided to select a leachant solution strength of 1.5 g/L and a leachant concentration of 3.0 kg NaCN/t (dry basis) of ore. This selection of leachant conditions was considered to be optimum, based on the results of the bottle rolls test program.
This experiment was run over a 38-day period, with the accumulated gold recovery reported approximately every 10 days. Figure 3 displays the gold recovery profile as well as concentration profiles of other dissolved metal ions in the recycled leach liquor over the duration of the experiment.

The final gold recovery figure was approximately 58% at a crush size of 80% passing 1/3 inch (9.5 mm). This modest recovery was probably the result again of unliberated gold brought about, in part, by the atypically low head grade value of 0.25 g/t. It will be shown later that higher grade ore material (in the range of 2 g/t) gives much better recoveries at this approximate crush size and that such material is consequently more amenable to leaching action.

A pervasive problem with most leaching operations relates to the influence or interference of other dissolved metal species (such as copper and iron) have on the processing or recovery of the solubilized gold from heap leach solutions. Some species tend to compete with gold by reacting with the available cyanide complexes. The two prominent and most commercially used gold recovery processes are carbon adsorption (Carbon-in-Column (CIC)) and Merrill Crowe (Zinc Precipitation). Both of these are quite sensitive to the presence of extraneous metal ions[9].

FIGURE 3



Mispec Core – Recovery of Gold vs. Time
50.61 kg ore, 10" column, Room Temperature
3 kg NaCN/t ore
Application Rate: 0.003 gallons/minute foot^2
Head Grade: 0.25 g/t Au
NaCN Solution Strength: 1.5 g/L
Crush Size: 80% passing 1/3" (9.5 mm)
pH: 11

The test revealed that the build-up of metal ions in the recycled leach solution is quite significant. For example, after ten days of operation, the copper concentration is approximately 175 mg/L. This concentration increases to approximately 620 mg/L at the end of the 38-day period. Similar trends can be seen for iron and zinc (Figure 3).

The dissolution of contained copper along with the gold can often foul leach solutions by reducing the availability of free cyanide for reaction with the gold. High-copper ores, such as those at Cape Spencer, tend to require greater consumptions of sodium cyanide to lessen the effects of such parallel reactions, thereby allowing for acceptable gold recoveries.

A second column experiment revealed much better gold recoveries. This time, the Mispec ore grade was on average 2.12 g/t, the solution strength and leachant concentration were 2 g/L and 1.5 kg NaCN/t ore, respectively, and the ore was crushed to -1.6 cm (which is slightly coarser than the previous column test). After 56 days of leaching, the recovery of gold was approximately 85%, which is about a 30% improvement over the previous test (Figure 3). As demonstrated by the rolls test, such an improvement may be partly attributed to the differences in head grades of the samples used for the two runs.

With respect to crush size in relation to liberation, the .98 cm to 1.63 cm range tested is considered the lower practical limit for most commercial crushers. As well, the expense of grinding for further liberation at a finer particle size would be hard to offset considering the low-grade nature of the ore. From an engineering point of view, finer crushed ore sizes would not be a viable option because of the adverse effect this would have on the permeability and management of the ore heaps.

Brominated Hydantoin Leaching (Bio-d)

Several rolls tests were carried out on Cape Spencer surface ores using a brominated hydantoin leachant having the chemical composition 1.3 - dibromo - 5.5 - dimethyl hydantoin. Unlike cyanide, the leachant, known as Bio-d because of its bio-degradable properties, is relatively nontoxic and poses minimal threat by its exposure to the environment. The Bio-d itself is an oxidizing agent, and is

used in conjunction with bromide salts (typically sodium bromide) that serve to enhance the solubilization of gold. Details of the reaction mechanics associated with Bio-d have been well investigated and these are discussed quite thoroughly elsewhere[10,11,12].

Table 3 presents separate leach data for Mispec and Gordex surface ores. The Bio-d and NaBr concentrations and solution strengths were varied over fairly broad ranges to test their effects on gold extraction. As well, the pH of the leach solution was adjusted to test gold recovery under both acidic and basic conditions. Compared to sodium cyanide, which has to operate under a highly alkaline medium, the Bio-d leachant system can operate over a broad pH range, giving way to greater flexibility in processing conditions.

For the Gordex surface sample, maximum gold recoveries of around 98% were achieved under alkaline conditions at a Bio-d and NaBr concentration ratio of 171 and 886 kg/tonne (ore), respectively. Acidic conditions were found to be slightly more favorable for the Mispec sample, with a recovery of approximately 91% achieved at similar Bio-d and NaBr concentrations of 171 kg/t (ore). However, for both samples, the dependency of gold recovery on the tested pH range was found to be quite modest and should not have a major bearing in determining optimum processing conditions.

As a trend, increases in both Bio-d and NaBr concentrations over the tested range resulted, with some minor inconsistencies, in improved gold recovery. A similar trend can be seen when the Bio-d concentration is increased while maintaining the NaBr concentration constant. The maximum recoveries are consistent with those obtained using sodium cyanide (see Tables 1 and 2)

TABLE 3
Results of Rolls Testing of
Cape Spencer Surface Ores Using Bio-d

SOLUTION STRENGTH g/L	CONCENTRATE kg NaBr t ORE	BIO-D CON. // SOLN. STRENGTH (kg. BIO-D/t ORE // g/L)			pH
		1.71/0.5	51.4//15	171//50	
		% GOLD RECOVERY			
(A)					
20	68	15.91	79.97	84.70	>8.5
50	171	17.08	87.02	94.67	>8.5
250	856	13.09	86.90	98.10	>8.5
20	68	49.24	45.72	86.85	<2.5
50	171	45.59	58.81	89.01	<2.5
250	856	60.50	72.82	94.03	<2.5
(B)					
20	68	32.99	88.24	79.41	>8.5
50	171	27.87	87.22	89.31	>8.5
250	856	33.37	80.56	79.45	>8.5
20	68	37.82	69.84	78.44	<2.5
50	171	34.12	86.44	91.30	<2.5
250	856	34.64	78.65	91.24	<2.5

A: Gordex Surface Ore
Ave. Assay: 1.80 g/t Au
Test Period: 48 hours

B: McNamara Surface Ore
Ave. Assay: 0.67 g/t Au
Test Period: 48 hours

Although the recoveries achieved using the Bio-d leachant system were quite encouraging, the consumption of both the Bio-d and NaBr reagents at optimum concentrations is considered to be very high by leaching standards. Such high consumptions would render this leachant system unattractive with respect to its applicability to the low-grade Cape Spencer ores; considering the market prices of Bio-d and NaBr are in the order of $1.75 and $0.68 per pound, respectively.

However, the chemical manufacturer of the leachant states that commercial consumptions are typically much lower than the lab tests indicate. This suggests the process simulation test work may not have been an accurate assessment of the Cape Spencer deposits. Further test work is required to confirm the current results and to prove the representativeness of the technique in assessing commercial performance.

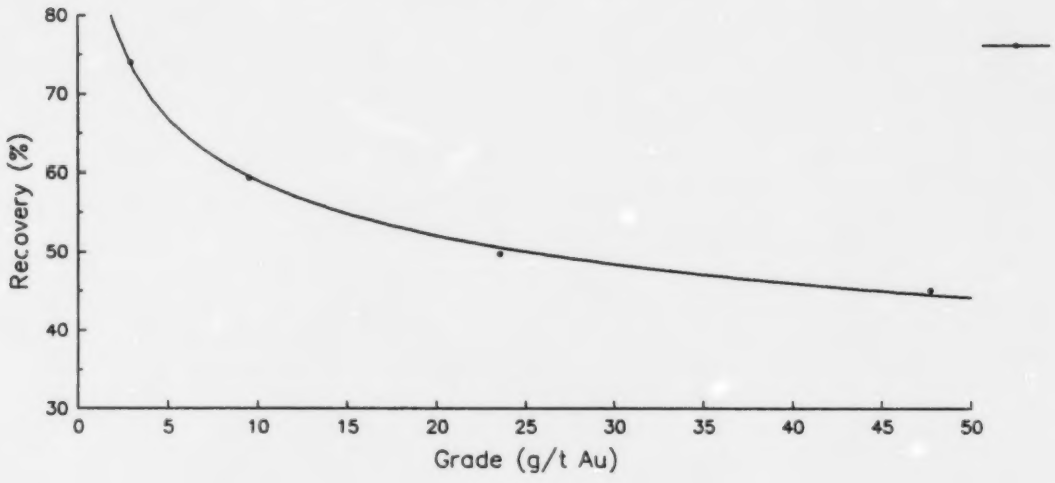
Gravity Concentration

Mispec surface ore was tested for its separability by gravity concentration using the Mozley separator. The surface material is highly oxidized as demonstrated by the mineralogical examination previously discussed and contains high proportions of free, native gold. Consequently, it was felt that gravity concentration may show some potential in concentrating or recovering the gold.

Figure 4 displays the grade and recovery curve determined for the Mispec surface ore. This curve was calculated based on the test data of two separate size fractions (-2000 micrometres +100 micrometres and -100 micrometres) of the same sample, and the results of these two size fractions were then combined to produce the indicated curve. The testing included the two size fractions because the technique requires the application of two different table designs (flat tray for the fine fraction and v-tray for the coarse fraction) to effectively test over this particle size range.

FIGURE 4

Grade and Recovery Curve for Gravity
Concentration of Cape Spencer Surface Ore
Using a Mozely Mineral Separator



Calculated Head Assay: 1.02 g/t Au
Sieve Size: -2000 micrometres
Table Design: Flat Tray, -100 micrometres
V-tray, -2000 +100 micrometres

The results of the gravity tests were somewhat encouraging. At a recovery of 60%, the corresponding grade and concentration ratio turned out to be approximately 9.5 g/t and 9 to 1, respectively. It is expected that a complete gravity circuit would improve on the grade and recovery relationship.

Having been oxidized, the surface ore is very friable and is the source of a considerable amount of fines. When these fines are present in heap leaching piles, they reduce the permeability of the piles, thereby hindering the kinetics and effectiveness of the leaching action. Although careful blending and/or agglomeration would alleviate this problem to some degree, it is possible that separate processing of the surface material by gravity means (followed by cyanidation) may be an economical and manageable way of handling this material.

3.2 Lake George

Significant gold mineralization was discovered in the hanging wall of the 850-foot level of the Lake George antimony mine. A sample of this mineralized showing ("ore") was obtained for testing purposes. The mill tailings, known to contain gold, were also sampled as part of the test program.

A mineralogical examination of the underground samples was completed and the results form part of the study completed by Wittech[7]. The extent of the examination was similar to that discussed under Section 3.1 for the Cape Spencer samples.

Both sample types were tested for their amenability to leaching by sodium cyanide using the rolls technique. As an alternative, the samples were preconcentrated using the Mozley gravity separator followed by cyanidation of the gravity concentrates.

Mineralogy

Two samples were tested separately for their mineralogical makeup and gold association. These consisted of a gravity concentrate of mill tailings and an ore sample. The gravity concentrate of mill tailings comprised the following mineral assemblage: primarily pyrite, with lesser amounts of arsenopyrite, pyrrhotite, sphalerite, stibnite (the predominant antimony mineral), and others. There were no detectable amounts of native gold mineralization; however, the gold may occur in a submicroscopic association with fine-grained arsenopyrite. The mineral assemblage for the ore material comprised arsenopyrite and pyrite with minimal native gold grains. The gold occurred primarily within microfractures of arsenopyrite.

When processed by conventional leaching methods, both of these samples exhibit behaviors that are consistent with those of refractory-type ores[13].

Sodium Cyanide Leaching

A range of sodium cyanide leaching conditions were tested on the ore samples obtained at the 850-foot level, and the results of this test work are reported in Table 4. The average head assay was 10.20 g/t Au, which was much higher than that of the Cape Spencer samples.

Over the range of NaCN solution strengths and concentrations tested, very modest returns of gold were achieved using the rolls technique. This suggests the highly refractory nature of the gold association, as indicated by the mineralogical studies. Maximum extraction of gold was 5.5% using 0.223 kg NaCN/t of ore at a solution strength of 0.149 g/L. Increases in the leachant solution strength and concentration over the range tested resulted in progressively poorer recoveries. It is evident by these results that preoxidation as a means of liberating the gold before cyanidation would be needed to achieve acceptable recoveries.

Leaching test work of the tailings samples consisted of a single rolls experiment on a gravity concentrate using 0.233 kg NaCN/t of ore at a solution strength of 0.149 g/L. Gold extraction was approximately 13.3% (at a grade of 11.2 g/t Au) of that contained in the concentrate, which translates into an overall recovery of approximately 1% based on the feed gold content prior to gravity concentration.

TABLE 4
Results of Rolls Testing of Lake George Gold Sample

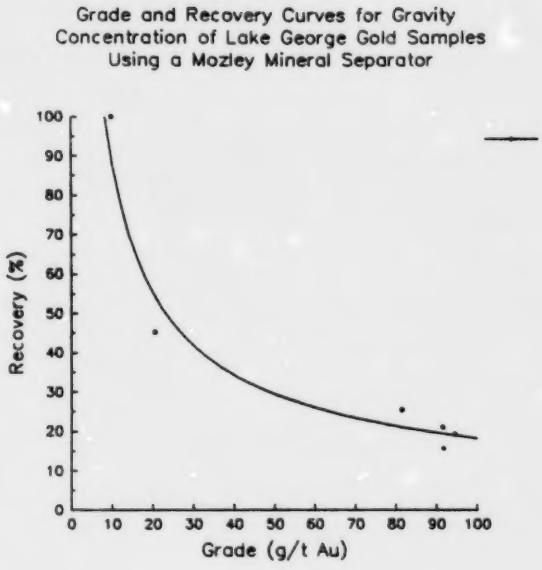
NaCN Soln. Strength (g/L)	NaCN Concentration (kg NaCN/t Ore)			
	0.223	0.669	1.338	2.676
	% GOLD RECOVERY			
0.074	3.48	-	-	-
0.149	5.50	3.55	-	-
0.297	4.49	1.55	3.59	-
0.446	-	0.83	1.78	2.35
1.784	-	-	0.75	1.74
3.568	-	-	-	1.03

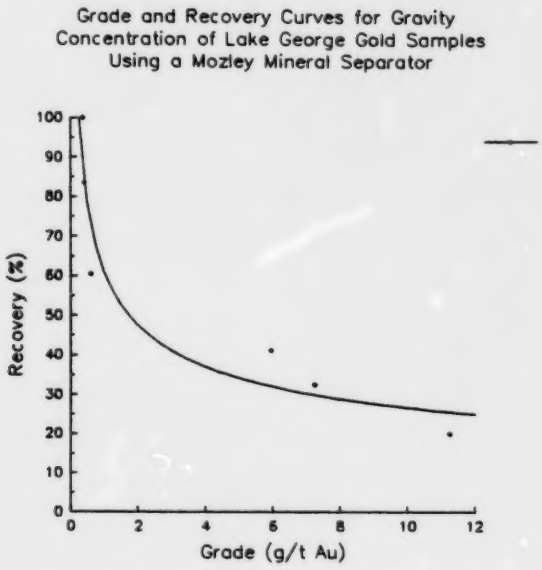
Head Assay: 10.20 g/t Au
Temperature: 22°C
Test Period: 48 hours
Sample Sieve Size: -200 mesh (-75 micrometres)

Gravity Concentration

Gravity concentration using the Mozley separator was tested on both the tailings and ore samples. Results are presented in Figure 5 in the form of grade and recovery curves.

FIGURE 5





(a) Durham Gold Ore
Head Assay: 10.0 g/t Au (calculated)
Sieve Size: -2000 micrometres
Table Design:
Flat Tray: -100 micrometres
V-Tray: -2000 +1000 micrometres

(b) Durham Mill Tailings
Head Assay: 0.35 g/t Au
Sieve Size: -100 micrometres
Table Design: Flat Tray

For the ore samples having a calculated head grade of 10.0 g/t Au and a crush of -2000 micrometres, the grade and recovery curve is shown in Figure 5(a). The curve shows rather poor recoveries over the range tested. For example, at a concentrate grade of about 20 g/t Au, the corresponding recovery is only 55%, giving a concentration ratio (concentrate grade/head grade) of approximately two. Higher grade concentrates result in further decreases in the recovery values. These poor recoveries can be partially attributed to the moderate specific gravities of the host minerals (essentially arsenopyrite and pyrite) relative to the gangue material. It is possible that flotation of arsenopyrite and pyrite may improve the grade and recovery relationship.

Similar results were obtained with mill tailings, as shown in Figure 5(b). This material was determined to have a much lower head grade (0.35 g/t Au) than that reported for the ore (which was in the order of 10.0 g/t Au), and a fine particle size of less than 80% - 200 Tyler mesh. The latter was a consequence of the grinding targets of the mill.

At 55% recovery, the concentration ratio was determined from the graph to be roughly 2.8, giving an approximate concentrate grade of 1.0 g/t Au. This is a marked improvement over that achieved with the ore material. The low gold content of the tailings coupled with the moderate specific gravities of the host minerals are thought to be responsible for such modest results.

Although the use of a gravity circuit would probably significantly improve the performance, these tests usually give a good idea of the relative effectiveness of the approach. A commercial gravity circuit would likely consist of rougher, cleaner and scavenger units operated under continuous conditions.

3.3 Alcida Property

The Alcida property, held by Corona Corp., is located in northeastern New Brunswick. The deposit is part of the so-called West Gabbro Zone and has current average gold values in the order of 7 g/t. The samples used for this test work were acquired from a surface trench that was previously dug across the mineralized zone by Corona.

The samples underwent mineralogical examination, rolls experiments using sodium cyanide, and flotation and gravity beneficiation tests[7]. The leaching test work consisted of direct cyanidation of the crushed sample as well as of the flotation and

gravity concentrates. Calcination or roasting of the mineral concentrates was also included in an effort to determine its effect on gold recovery.

Mineralogy

Arsenopyrite is the major host mineral of the contained gold. Minor amounts of gold are also associated with rutile, chalcopyrite, and native gold. The gold is found mainly in microfractures and at grain boundary-intercystal surfaces within arsenopyrite, which is consistent with the nature of certain refractory ores[13].

Sodium Cyanide Leaching

Table 5 presents the results of the rolls test performed on the Alcida ore samples. The average assay of the samples tested was 4.34 g/t Au, which is in broad agreement with that reported as the average grade of the deposit.

TABLE 5

Results of Rolls Testing of Alcida Gold Deposits

NaCN Soln. Strength (g/L)	NaCN Concentration (kg NaCN/t Ore)			
	0.223	0.669	1.338	2.676
	% GOLD RECOVERY			
0.074	4.46	--	--	--
0.149	2.59	13.12	--	--
0.297	2.62	8.00	1.338	--
0.446	--	5.96	10.06	12.54
1.784	--	--	8.52	8.39
3.568	--	--	--	9.06

Head Assay: 4.34 g/t Au
Temperature: 22°C
Test Period: 48 hours
Sample Sieve Size: -200 mesh (-75 micrometres)

Of the twelve tests carried out under various leachant conditions, none showed encouraging recovery values. The best recovery value reported is 13.12%, at a sodium cyanide solution strength and concentration of 0.149 g/L and 0.699 kg NaCN/t of ore, respectively. The other data points are scattered and do not seem to reflect any consistent pattern or trend. In general, however, the data shows the refractory nature of the ore matrix. This is consistent with the results of the mineralogical work and shows good agreement with the results of the Lake George samples (Table 4) regarding their degree of refractoriness. Other leaching experiments were carried out on flotation and gravity concentrates and the results of these will be discussed under the respective sections.

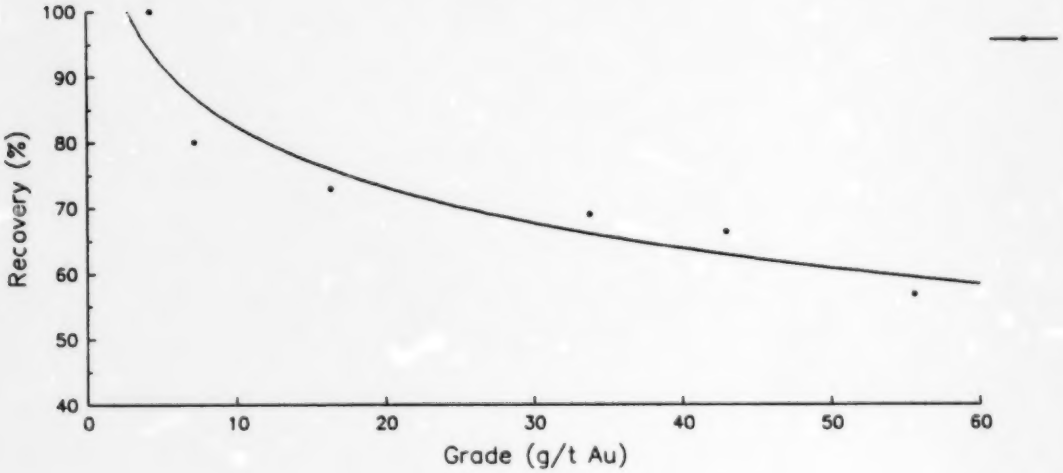
Gravity Concentration

The results of this test work are given in Figure 6, for samples ground to -100 micrometres. This fine grind was necessary to liberate the fine-grained arsenopyrite that is host to the majority of gold contained in the ore.

The grade and recovery curve shown in this figure demonstrates the effect of gravity concentration on this ore. The recoveries achieved were a considerable improvement over recoveries from the Lake George samples and a slight improvement over those from the Cape Spencer tests. The fineness of the arsenopyrite particles is believed to be largely responsible for the poor recovery values.

FIGURE 6

Grade and Recovery Curve for Gravity Concentration of Alcida Gold Samples Using a Mozley Mineral Separator



Head Assay: 4.21 g/t Au
Sieve Size: -100 micrometres
Table Design: Flat Tray

For leaching purposes, a gravity concentrate was produced having a grade of approximately 56 g/t Au at a recovery of 57% (see grade/recovery curve). Cyanidation of this concentrate, at a leachant concentration of 4 kg NaCN/t ore managed to recover only 6.1% of the gold that was contained in the concentrate. This result further confirms the high refractory nature of the gold association.

The encouraging results achieved with flotation precluded further consideration of the gravity route.

Flotation

The flotation experiments were designed to recover the sulphide minerals, with arsenopyrite being the main component. The flotation conditions are detailed in Table 6.

TABLE 6
Flotation Conditions for Alcida Gold Sample

pH:	4 (adjusted using H_2SO_4)
Collector:	potassium amyl xanthate
Frother:	MIBC
Flotation Time Interval:	3 minutes
Grind Size:	-100 micrometres
Head Assay:	5.77 g/t Au

A concentrate grade of 16.3 g/t Au was achieved at a recovery value exceeding 91%. This was a marked improvement over that achieved with gravity concentration and is attributed to the affinity of the arsenopyrite particles to the flotation environment. The testing parameters were not optimized, so it is quite reasonable to suggest that some improvements to recovery could be made. An overall grade and recovery curve for this sample type was not produced.

The grade produced (16.3 g/t Au) is roughly in line with that required as feedstock for refractory-gold processing facilities. There are many oxidation technologies, both commercial and developing, that are currently available for assessment in specific situations; these include roasting, pressure leaching, bioleaching, etc.[2] For this investigation, the flotation concentrate was roasted in an effort to convert the matrix into a non-porous form that is amenable to gold recovery by cyanidation.

After a two-stage roast conducted at 400°C for a total of 21.5 hours (1st stage - 5.5 hours and 2nd stage - 16.0 hours), the concentrate was cyanided for two hours under

agitated conditions. For the leach, the concentrate was slurried to 30% solids with the cyanide concentration adjusted to 4 kg NaCN/t ore.

An analysis of the leach solution revealed that approximately 25% of the gold was recovered. This poor recovery, although a marked improvement over the results of the direct cyanidation tests, suggests that only partial oxidation of the ore took place during the roasting operation. It is quite possible that optimization of the roasting parameters would result in substantial improvements in recovery upon cyanidation.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The processability of gold test samples from the Cape Spencer, Lake George and Alcida deposits was tested with respect to leaching and gravity concentrations. The mineralogical makeup of the samples was reviewed in support of the processing work. Flotation was applied to the Alcida deposit as a prelude to roasting experiments.

The Cape Spencer samples were found to be non-refractory with respect to both cyanide and Bio-d leaching. Recoveries as high as 98% and 85% were achieved by the rolls and column techniques, respectively, for the cyanide leachant system, while recoveries of around 98% were achieved for Bio-d using the rolls test. Leachant consumptions of Bio-d were considered too excessive to warrant much further consideration. As well, the grade of the sample was shown to have some impact on the proportions of gold leached.

The Mispec surface ore of the Cape Spencer area was tested with respect to gravity concentration. According to the mineralogy, the surface material contains high proportions of free gold. Encouraging results were reported, reflecting a concentration ratio of approximately 9 at 60% recovery. In view of the friable nature

of the surface ore, preconcentration using gravity may have some merit as an alternative to heap leaching, thereby alleviating the need to deal with excessive fines in the heap leaching operation.

On the contrary, the other two ores (Lake George and Alcida) were found to be highly refractory with respect to direct cyanidation; this is consistent with the findings of the mineralogy investigation. Using the rolls technique, maximum recoveries of gold by cyanidization were determined to be 5% and 13% for the Lake George and Alcida samples, respectively. Beneficiation of Alcida ore was carried out using both flotation and gravity concentration operations, with the former proving to be the more effective for this ore type. Preoxidation of the flotation concentrate via roasting followed by cyanidation of the calcine resulted in improved gold extractions.

Gravity concentration of the Lake George ore and tailings samples proved to be effective in concentrating the gold but at the expense of recovery. Cyanidization of the gravity concentrates resulted in still poorer recoveries, confirming the highly refractory nature of these gold-containing samples.

4.2 Recommendations

Based on the results of this study, the following recommendations are proposed:

1. Further assessment of the Bio-d leachant system is required to determine the representativeness of the current results for the Cape Spencer area. This should be done in close consultation with the chemical manufacturer (Great Lakes Chemical Corp.) to ensure proper evaluation.

2. Gravity concentration seems to have merit for the Mispec or Cape Spencer surface ore and should be further evaluated on an integrated circuit basis.

3. In view of the presence of high concentrations of extaneous ions (such as Cu) in the leach solutions of Cape Spencer ores, a larger study should be commissioned to evaluate the effect of these ions on commercial and developing gold recovery technologies. As well, larger scale heap leach column tests would provide more accurate heap leach data of the Mispec deposit for scale-up purposes.

4. The resource potential of the Lake George gold occurrence would need to be further evaluated as a prerequisite to further processing considerations.

5. Roasting and other preoxidation technologies applicable to the Alcida refractory gold deposit need to be examined to determine the optimum technology for this application. Again, further resource definition is required in parallel to any process development efforts.

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